

CLAIMS

We claim:

1. An apparatus for measuring light absorption in a sample having a first index of refraction, the apparatus comprising:

a ring-down optical cavity formed by at least first and second spaced apart light beam reflectors to receive and reflect a light beam having a selected wavelength width and to establish a resonant mode for the light beam, the light beam being measured after the light beam has been reflected at least once from each reflector to determine the absorption of the light beam by the sample, the optical cavity comprising a medium having a second index of refraction; and

a container positioned in the optical cavity for containing the sample, the container comprising:

an outer surface having opposing first and second outer faces that are oriented to receive and transmit the light beam, the container including a first portion forming the first outer face having a third index of refraction and a second portion forming the second outer face having a fourth index of refraction; and

an inner surface forming a void for containing the sample, the inner surface having opposing first and second inner faces that are oriented to receive and transmit the light beam,

wherein the first and second outer faces of the container form first and second cavity/container interfaces, and the first and second inner faces of the

container form first and second container/sample interfaces,

wherein the first and second outer faces of the outer surface of the container are oriented at first and second angles, respectively, with respect to the light path of the light beam such that the light beam incident upon and exiting the first and second cavity/container interfaces is at approximately the Brewster's angle of the respective first and second cavity/container interfaces, and

wherein the first and second inner faces of the inner surface are oriented at third and fourth angles, respectively, with respect to the first and second outer faces of the outer surface such that the light beam incident upon and exiting the first and second container/sample interfaces is at approximately the Brewster's angle of the respective first and second container/sample interfaces.

2. The apparatus of claim 1 wherein the medium of the optical cavity comprises one of air, an inert gas, vacuum, a liquid or a solid monolith.

3. The apparatus of claim 1, further comprising a light source for providing the light beam having a selected beam wavelength width.

4. The apparatus of claim 1, wherein the light beam has a polarization parallel to the plane of incidence of upon each interface of the container.

5. The apparatus of claim 1 wherein the third index of refraction of the first portion of the container and the fourth

index of refraction of the second portion of the container are the same.

6. The apparatus of claim 5, wherein the first and second cavity/container interfaces are substantially parallel interfaces and the first and second container/sample interfaces are substantially parallel interfaces.

7. The apparatus of claim 5, wherein the container comprises UV-grade fused silica having an index of refraction of 1.46.

8. The apparatus of claim 1 wherein the sample comprises one of a liquid, gas, or solid.

9. The apparatus of claim 1, wherein the Brewster's angle of the first cavity/container interface is related to the second index of refraction and the third index of refraction and the Brewster's angle of the second cavity/container interface is related to the second index of refraction and the fourth index of refraction.

10. The apparatus of claim 1, wherein the cavity comprises a first medium between the first light beam reflector and the first outer face and a second medium between the second light beam reflector and the second outer face, the first medium having the second index of refraction and the second medium having a fifth index of refraction different from the second index of refraction.

11. The apparatus of claim 10, wherein the Brewster's angle of the first cavity/container interface is related to the second index of refraction and the third index of refraction and the

Brewster's angle of the second cavity/container interface is related to the fifth index of refraction and the fourth index of refraction.

12. The apparatus of claim 1, wherein the Brewster's angle of the first container/sample interface is related to the first index of refraction and the third index of refraction and the Brewster's angle of the second container/sample interface is related to the first index of refraction and the fourth index of refraction.

13. The apparatus of claim 1, wherein the light beam has at least one selected wavelength λ .

14. The apparatus of claim 13, wherein the selected wavelength λ is selected from a wavelength range of $0.3 \times 10^{-2} \mu\text{m}$ to $300 \mu\text{m}$ and the selected wavelength width is selected from a range of 0.001 cm^{-1} to 1 cm^{-1} .

15. The apparatus of claim 1, wherein the light beam is displaced by passage through the container and the first and second spaced apart light beam reflectors are in offset alignment to account for the offset in the optic axis of the light beam.

16. The apparatus of claim 1, wherein the container further comprises a capillary positioned inside the void formed by the inner surface and a sheath flow of a second medium between an outer surface of the capillary and the inner surface of the container, the sample being contained inside the capillary, wherein the capillary is oriented in the void at a fifth angle with respect to the inner surface so that light beam incident upon and exciting an interface between the inner surface of the

container and the sheath flow is at approximately the Brewster's angle of the interface, and light beam incident upon and exciting an interface between the sheath flow and the outer surface of the capillary is at approximately the Brewster's angle of the interface.

17. A container to be positioned in a ring-down optical cavity for containing a sample having a first index of refraction, the container to be used to facilitate measurement of light absorption in the sample, the container comprising:

an outer surface having opposing first and second outer faces that are oriented to receive and transmit a light beam, the container including a first portion forming the first outer face having a second index of refraction and a second portion forming the second outer face having a third index of refraction;

an inner surface forming a void for containing the sample, the inner surface having opposing first and second inner faces that are oriented to receive and transmit the light beam;

the first and second outer faces of the container forming first and second cavity/container interfaces; and

the first and second inner faces of the container forming first and second container/sample interfaces,

wherein the first and second outer faces of the outer surface of the container are to be oriented in the optical cavity such that the first and second cavity/container interfaces transmit and receive the light beam at an incidence angle approximately equal to the Brewster's angle

of the respective first and second cavity/container interfaces, and

wherein the first and second inner faces of the inner surface are oriented at first and second angles, respectively, with respect to the first and second outer faces of the outer surface such that the first and second container/sample interfaces transmit and receive the light beam at an incidence angle approximately equal to the Brewster's angle of the respective first and second container/sample interfaces.

18. The container of claim 17, wherein the second index of refraction of the first portion of the container and the third index of refraction of the second portion of the container are the same.

19. The container of claim 18, wherein the first and second cavity/container interfaces are substantially parallel interfaces and the first and second container/sample interfaces are substantially parallel interfaces.

20. The container of claim 19, wherein the container comprises UV-grade fused silica having an index of refraction of 1.46.

21. The container of claim 17, wherein the optical cavity in which the container is to be positioned comprises a medium having a fourth index of refraction.

22. The container of claim 21, wherein the Brewster's angle of the first cavity/container interface is related to the second index of refraction and the fourth index of refraction and the

Brewster's angle of the second cavity/container interface is related to the third index of refraction and the fourth index of refraction.

23. The container of claim 21, wherein the Brewster's angle of the first container/sample interface is related to the first index of refraction and the second index of refraction and the Brewster's angle of the second container/sample interface is related to the first index of refraction and the third index of refraction.

24. The container of claim 17, wherein the inner surface forming the void comprises a shaped inner surface, the shaped inner surface forming an inlet portion, an outlet portion and a central portion, the central portion having dimensions larger than the inlet portion and the outlet portion for containing a predetermined volume of sample.

25. The container of claim 17, wherein the inner surface forming the void comprises a shaped inner surface, the shaped inner surface forming an inlet portion, an outlet portion and a central portion, the central portion comprising a channel tilted at third and fourth angles relative to the first and second inner faces where the third and fourth angles are the Brewster's angle of the respective first and second container/sample interfaces.

26. The container of claim 25, wherein the central portion has dimensions larger than the inlet portion and the outlet portion for containing a predetermined volume of sample.

27. A method for measuring light absorption in a sample having a first index of refraction, the method comprising:

providing a light beam having a selected wavelength width that includes at least one selected wavelength λ ;

receiving the light beam in a ring-down optical cavity formed by at least first and second spaced apart light beam reflectors to receive and reflect the light beam and to establish a resonant mode for the light beam, the optical cavity comprising a medium having a second index of refraction;

positioning a container in the optical cavity for containing the sample, the container having opposing first and second outer faces that are oriented to receive and transmit the light beam, and opposing first and second inner faces forming a void for containing the sample which inner faces are oriented to receive and transmit the light beam, the first and second outer faces forming first and second cavity/container interfaces and the first and second inner faces forming first and second container/sample interfaces, wherein positioning the container in the optical cavity comprises:

orienting the first and second outer faces of the container at first and second angles, respectively, with respect to the light path of the light beam such that the first and second cavity/container interfaces transmit and receive the light beam at an incidence angle approximately equal to the Brewster's angle of the respective first and second cavity/container interfaces; and

orienting the first and second inner faces of the container at third and fourth angles, respectively, with respect to the first and second outer faces such

that the first and second container/sample interfaces transmit and receive the light beam at an incidence angle approximately equal to the Brewster's angle of the respective first and second container/sample interfaces; and

receiving the light beam after the light beam has been reflected at least once from each reflector to determine the absorption of the light beam by the sample.

28. The method of claim 27, wherein the third index of refraction and the fourth index of refraction are the same.

29. A method for measuring light absorption in a sample having a first refractive index, the method comprising:

providing a light beam having a selected wavelength width that includes at least one selected wavelength λ ;

receiving the light beam in a ring-down optical cavity formed by at least first and second spaced apart light beam reflectors to receive and reflect the light beam and to establish a resonant mode for the light beam, the optical cavity comprising a medium having a second index of refraction;

positioning a container in the optical cavity for containing the sample, the container having first and second outer faces that are oriented to receive and transmit the light beam, and first and second inner faces forming a void for containing the sample which inner faces are oriented to receive and transmit the light beam, the first and second outer faces forming first and second cavity/container interfaces and the first and second inner faces forming first and second container/sample interfaces;

transmitting and receiving the light beam at the first cavity/container interface at an incidence angle approximately equal to the Brewster's angle of the first cavity/container interface;

transmitting and receiving the light beam at the first container/sample interface at an incidence angle approximately equal to the Brewster's angle of the first container/sample interface;

transmitting and receiving the light beam at the second container/sample interface at an incidence angle approximately equal to the Brewster's angle of the second container/sample interface;

transmitting and receiving the light beam at the second cavity/container interface at an incidence angle approximately equal to the Brewster's angle of the second cavity/container interface; and

receiving the light beam after the light beam has been reflected at least once from each reflector to determine the absorption of the light beam by the sample.

30. The method of claim 29, wherein the container comprises a first portion at the first outer face having a third index of refraction and a second portion at the second outer face having a fourth index of refraction.

31. The method of claim 30, wherein the third index of refraction and the fourth index of refraction are the same.

32. The method of claim 30, wherein the Brewster's angle of the first cavity/container interface is related to the second index of refraction and the third index of refraction and the

Brewster's angle of the second cavity/container interface is related to the second index of refraction and the fourth index of refraction.

33. The method of claim 30, wherein the Brewster's angle of the first container/sample interface is related to the first index of refraction and the third index of refraction and the Brewster's angle of the second container/sample interface is related to the first index of refraction and the fourth index of refraction.